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# Performance evaluation of open core gasifier on multi-fuels

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**Abstract**

Sardar Patel renewable energy research institute (SPRERI) has designed and developed open core, throat-less, down draft gasifier and installed it at the institute. The gasifier was designed for loose agricultural residues like groundnut shells. The purpose of the study is to evaluate the gasifier on multi-fuels such as babul wood (*Prosopis juliflora*), groundnut shell briquettes, groundnut shell, mixture of wood (*Prosopis juliflora)* and groundnut shell in the ratio of 1:1 and cashew nut shell. The gasifier performance was evaluated in terms of fuel consumption rate, calorific value of producer gas and gasification efficiency. Gasification efficiency of babul wood (*Prosopis juliflora*), groundnut shell briquettes, groundnut shell, mixture of *Prosopis juliflora* and groundnut shell in the ratio of 1:1 and cashew nut shell were 72%, 66%, 70%, 64%, 70%, respectively. Study revealed that babul wood (*Prosopis juliflora*), groundnut shell briquettes, groundnut shell, mixture of wood (*Prosopis juliflora*) and groundnut shell in the ratio of 1:1 and cashew nut shell were satisfactorily gasified in open core down draft gasifier. The study also showed that there was flow problem with groundnut shell.


*Keywords:* Open core gasifier; Gasification efficiency; Babul wood (*Prosopis juliflora*); Cashew nut-shell; Groundnut shell briquettes; Groundnut shell

## 1. Introduction

Sardar Patel renewable energy research institute (SPRERI) has developed a throat-less, down draft gasifier, which can convert biomass fuels into a combustible fuel gas called producer gas, by a process involving thermo chemical conversion with a limited quantity of air (equivalence ratio = 0.25–0.30) [1]. The producer gas can be used for thermal applications like boilers, drying units, chemical heating, cooking, ceramic kilns etc. through combustion of the gas in a burner.

General need to use non-woody fuels for gasification is to avoid deforestation. Crop residues are most abundantly produced in India. As per the estimates, about 249.78 Mt of surplus biomass was available in 2001 from all sources like agro-processing residues, grasslands, forests, roadsides, agro-forestry and degraded habitats. Their availability is likely to increase to about 384.51 Mt by 2015 [2]. Substantial quantity of this surplus biomass could be utilized for energy generation. Generally, crop residues are seasonal so there must be a unique system that can work on multi-fuels. The objective of the study was to carry out performance evaluation of the SPRERI open core gasifier on multi-fuels.

## 2. Material and methods

### 2.1. System description

The schematic diagram of a $50\,kg\,h^{-1}$ open core gasifier developed at SPRERI is shown in Fig. 1. The gasifier consists of a well-insulated cylindrical reactor, rotating type stainless-steel grate, an induced draft fan and an aerated jet-type producer gas burner. The reactor is a cylindrical mild steel (I.S. 2062) shell insulated from outside with cerawool of 50 mm thickness and covered with an aluminum sheet of 26 gauge. The air distribution unit that supplements the air taken through the open top consists of four air tuyeres of 25 mm diameter. These side tuyeres are placed at 400 mm above the grate. The grate was fabricated from stainless-steel 310 and was mounted with a shaft in the ash pit tank. The grate area ($0.31\,m^2$) was designed from specific gasification rate (SGR) of

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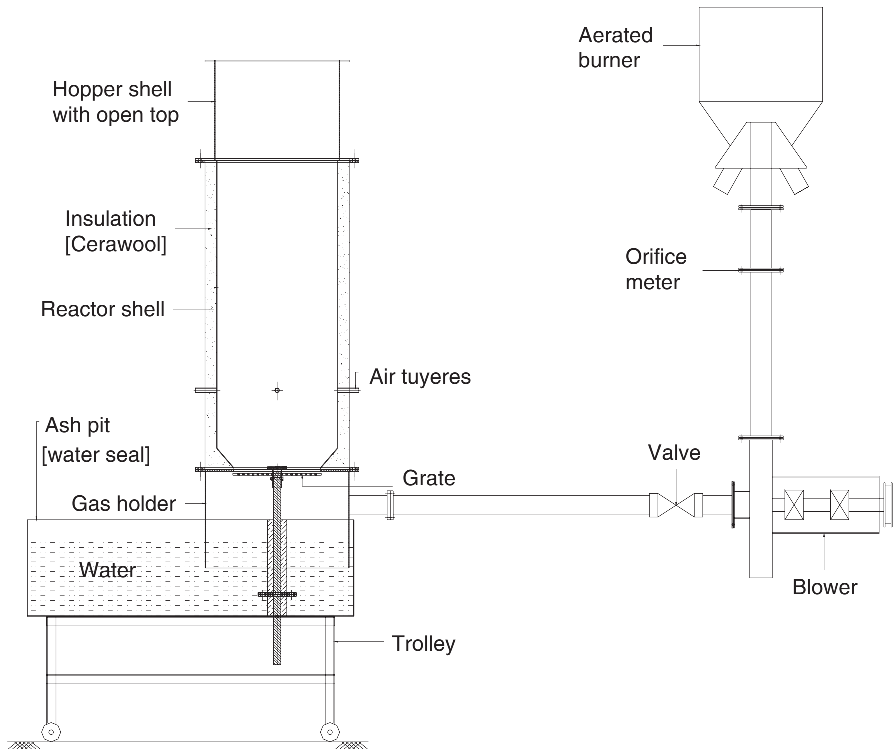


Fig. 1. Schematic diagram of 50 kW open core, throat-less down draft gasifier.

$160\,kg\,h^{-1}\,m^{-2}$ and the fuel input rate of $50\,kg\,h^{-1}$. The ash falls into the ash pit tank, which was fabricated from a mild steel sheet of 3 mm thickness containing water. The volume of the ash pit ($0.068\,m^3$) was sufficient to allow operation without ash removal for many hours [1,3]. The technical specifications of the gasifier system are given below.

| | |
|---|---|
| Type | : down draft, open core. |
| Biomass | : groundnut shell, wood, agro–residue briquettes. |
| Biomass consumption rate | : $50\,kg\,h^{-1}$. |
| Capacity | : $625\,MJ\,h^{-1}$. |
| Ash removal unit | : manual rotating type. |
| Fuel feeding | : manual. |
| Gas discharge | : by electric suction blower. |

### 2.2. System operation and measurements

The gasifier was operated according to the procedure prescribed by the ministry of non-conventional sources of energy (MNES) [4]. Proximate analysis of fuel was carried out before the test by using the method suggested by ASTM and SPRERI. [5,6]. A bomb calorimeter (Advance Research Instruments Company) was used to measure the gross heating values of biomass fuel. Initially 40 kg charcoal pieces (10–50 mm long) were loaded up to the air nozzle level, then fuel was loaded up to the top of the gasifier. The blower was started, drawing air for gasification through the top of the reactor and through the air tuyeres. By holding a flame at the air tuyeres one by one ignited the fuel bed, which sucked in the flame to ignite the bed. After some time, the producer gas obtained becomes combustible and was ignited at the burner. At the end of the test, first the gas control valve was closed and thereafter the blower was turned off. Finally, the wood feeding port and air tuyeres of the gasifier were closed. A globe valve was provided with the blower to control gas flow rate. A stand with ladder was provided with the system for facilitating the manual fuel feeding and other operations. Proximate analysis was done to analyze the feedstock. Fixed carbon (FC) was determined using material balance [5,6]. Analysis of the different feedstock is given in Table 1 [7].

Performance measurements were taken after the stable operation of the system was observed, i.e., constant raw gas temperature. Generally, this took 1.5–2 h from ignition. The fuel consumption rate (FCR) was measured by recharging the gasifier on an hourly basis by filling the gasifier volume to a predetermined level that was at the top of the gasifier hopper. The grate was operated at regular interval to remove ash accumulated on the grate. Chromel–Alumel type K thermocouples and a digital multichannel temperature indicator were used to measure temperature. Water-filled U tube manometers were used to measure the pressure drop across the gasifier and at the orifice meter. Producer gas samples were collected by water displacement method and analyzed by using gas

Table 1
Physical and thermal properties of different biomass fuels

| Characteristics | Biomass fuels | | | | |
|---|---|---|---|---|---|
| | Babul wood (*Prosopis juliiflora*) | Groundnut shell briquettes made from groundnut shell powder | Groundnut shell | Mixture of babul and groundnut shell in the ratio of 1:1 | Cashew nut shell |
| Size | | | | | |
| Diameter (mm) | 20–35 | 35 | Not measured | Not measured | Not measured |
| Length (mm) | 30–80 | 30–80 | | | |
| Bulk density ($kg\,m^{-3}$) | 407 | 618 | 66.47 | 114.65 | 481.83 |
| Angle of slide (deg.) | 18.8 | Not measured | 37.77 | 30.37 | 18.85 |
| Moisture content (% (wb)) | 8.81 | 9.02 | 8 | 8.40 | 6.45 |
| Volatile matter (% (db)) | 83.23 | 80.5 | 82.7 | 82.96 | 79.54 |
| Ash content (% (db)) | 1.07 | 7.92 | 5.559 | 3.31 | 1.53 |
| Fixed carbon (% (db)) | 15.70 | 11.58 | 11.734 | 13.71 | 18.93 |
| Calorific value ($MJ\,kg^{-1}$) | 16.82 | 17.40 | 17.40 | 17.11 | 17.80 |
| Oil content (%) | Not measured | Not measured | Not measured | Not measured | 8.30 |

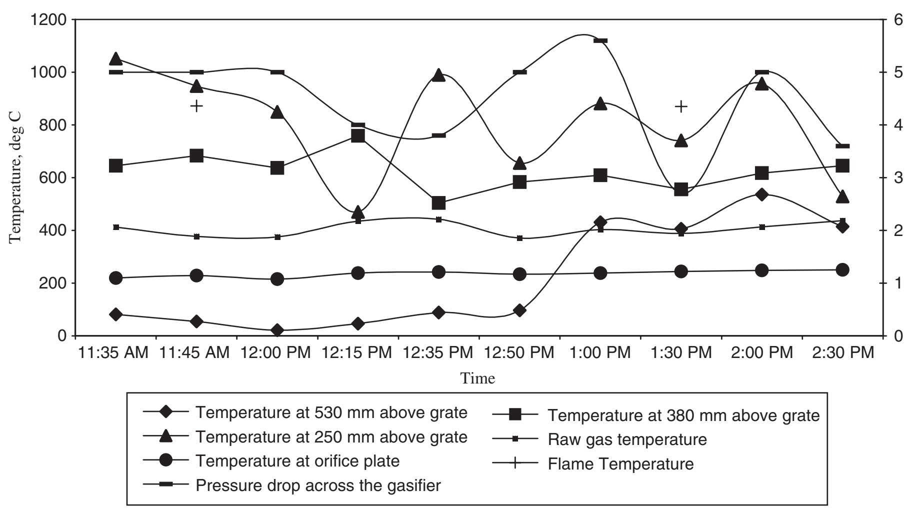


Fig. 2. Variation in temperatures and pressure drop across the gasifier for groundnut shell.

chromatography (Netal Chromatographs, Baroda, Gujarat, India). The chromatograph consisted of two columns—Molecular sieve and Porapack N as stationary media and Argon as carrier gas. Chromatograph used TCD as detector. 'INSREF' Junker's gas calorimeter (Instrumentation and refrigeration of India, Chennai, India) was also used to verify the calorific value of the producer gas, the combustion of a known volume of gas to heat steadily flowing water and measuring the rise in temperature of a measured volume of water.

A calibrated orifice plate was used to determine the flow rate of producer gas. The measurement parameters—fuel consumption rate, temperature at different zones of the gasifier, producer gas temperature at the gasifier exit, flame temperature, pressure drop across the gasifier, pressure drop at orifice plate, and calorific value of producer gas—were constantly monitored.

## 3. Result and discussion

The system was operated at an average gas flow rate of 100–130 $Nm^3\,h^{-1}$. The variations in the temperature of different zones of the gasifier with respect to time were noted for all fuels and it was observed that temperatures were almost constant for babul wood and groundnut shell briquettes. It was also observed that there was large variation in the temperatures at 250 mm above the grate and pressure drop across the gasifier for groundnut shell, resulting in very poor quality of producer gas (see Fig. 2). To maintain uniform fuel flow poking/ramming at a regular interval (30 min) was required. This may be due to improper flow of fuel because of its low bulk density. To overcome this problem the gasifier was operated on a mixture of babul wood (*Prosopis juliiflora*) and groundnut shell in the ratio of 1:1. The result was encouraging and

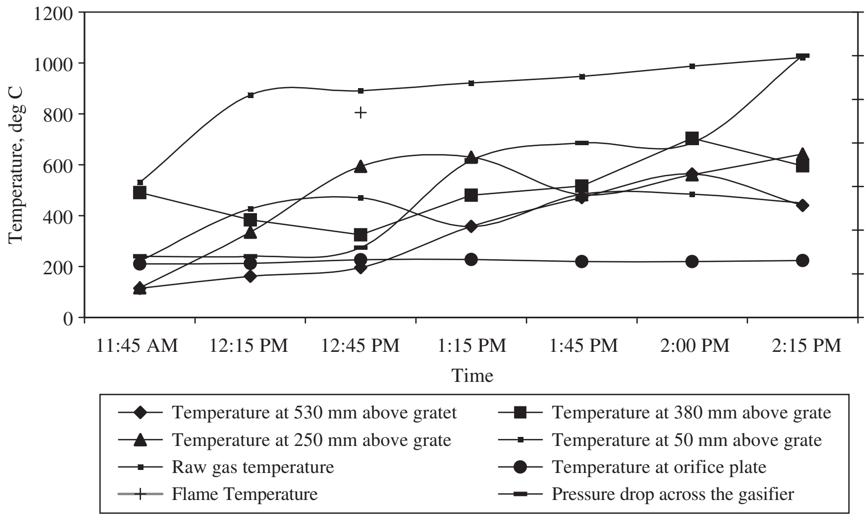


Fig. 3. Variation in temperatures and pressure drop across the gasifier for a mixture of babul wood (*Prosopis juliflora*) and groundnut shell in the ratio of 1:1.

Table 2
Performance of gasifier at different biomass fuels

| Parameters | Biomass fuels | | | | |
|---|---|---|---|---|---|
| | Babul wood (*Prosopis juliiflora*) | Groundnut shell briquettes | Groundnut shell | Mixture of Babul wood (*Prosopis juliiflora)* and groundnut shell in the ratio of 1:1 | Cashew nut shell |
| Fuel consumption rate (kg $h^{-1}$) | 41.1 | 53.2 | 37.66 | 40 | 47 |
| Producer gas flow rate ($Nm^3 h^{-1}$) | 113.08 | 127.23 | 104.16 | 97.51 | 130 |
| Calorific value of producer gas (MJ $Nm^{-3}$) | 4.39 | 4.79 | 4.37 | 4.47 | 4.52 |
| Cold gas efficiency (%) | 72 | 66 | 70 | 64 | 70 |
| Gas production ($m^3 kg^{-1}$) | 2.75 | 2.39 | 2.76 | 2.43 | 2.76 |

variation in temperatures and pressure drop was less compared to groundnut shell (see Fig. 3). It shows that flow of material in the gasifier can be improved by the addition of dense biomass.

The gasifier performance with different fuels show that the calorific value of producer gas varied in the range of 4.3–4.8 MJ $m^{-3}$ and cold gas efficiency in the range of 64–70% (Table 2).

## 4. Conclusion

Babul wood, groundnut shell briquettes, groundnut shell, 1:1 mixture of babul wood and groundnut shell were satisfactorily gasified in a 50 kW open core, down draft gasifier. The study also showed that there was flow problem with groundnut shell, which was improved by a using mixture of babul wood and groundnut shell in the ratio of 1:1.

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